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PHYSIOGRAPHICALLY UNFINISHED
ENTRANCES TO SAN FRANCISCO BAY

BY

RULIFF S. HOLWAY

UNIVERSITY OF CALIFORNIA PRESS
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INTRODUCTION

That the Golden Gate stands unique as the single deep-water passage through the westernmost ridge of the Coast Ranges of California is a fact which has long been emphasized in geographical literature. From the standpoint of the student of the influence of topography on man's movements, the importance of this opening in controlling the development of the state of California can hardly be overestimated. When considered, however, from the standpoint of the physiographic evolution of the Coast Ranges, the Golden Gate is seen to be merely that par-

ticular one of several openings through the mountains which happens to be at the special stage of development and at the particular hypsometric level necessary to admit tidewater freely to the interior valley now partially occupied by San Francisco Bay. There exist at least six other openings which might have been equally serviceable to man had the action of the erosional and diastrophic forces that control the evolution of topographic forms been varied but slightly in amount or in localization.

It should be borne in mind that the coast line of central California is mountainous, rising abruptly from the sea, frequently with slopes so precipitous that the only possible roadway along the coast is on top of the sea-cliff hundreds of feet above the water. Yet should the region around San Francisco Bay be uniformly depressed but 250 feet below its present level there would be not the single Golden Gate of today but six tidewater entrances to the bay, as may be seen in plate 12, on which the present bay is represented by the darker blue and the five new entrances which would result from the supposed subsidence by the lighter shade. A subsidence of an additional one hundred feet would connect San Francisco Bay with Monterey Bay through the valley of Coyote Creek, thus adding a seventh entrance and converting the Santa Cruz Mountains into an island.

As has been intimated, the physiographic interest in the facts to be presented here lies in the extreme ruggedness of the coast. The mountain ridge separating the bay from the ocean rises almost as abruptly from the one as it does from the other. This ruggedness suggests youthfulness or early maturity as the stage of the present topography in the geographic cycle, but some of the six passages through the ridge have characteristics belonging rather to late maturity or even to old age. Anticipating the descriptions to be given later, it may be postulated that in the vicinity of the bay a region well advanced toward old age in a former cycle has recently been subjected to diastrophic changes which have caused the development of much youthful topography without destroying many areas bearing features typical of maturity or of age. The six cross-valleys to be considered have quite different origins, and the purpose of this paper is to

describe the characteristics and to discuss the probable evolution of each of these, at present, physiographically unfinished entrances to San Francisco Bay.

GENERAL PHYSIOGRAPHY OF THE VALLEY OF SAN
FRANCISCO BAY

San Francisco Bay has an area of about four hundred square miles, including the partially shut-off northern portion, which has the local name of San Pablo Bay. The axis of the bay as a whole conforms to the prevailing NW-SE trend of the Coast Ranges. The town of Petaluma is at the extreme northwesterly limit of tidewater; from that point the distance by way of Petaluma Creek, San Pablo Bay, and the main San Francisco Bay to the extreme southeasterly tidewater town of Alviso is nearly seventy miles. The Golden Gate is approximately midway between these two points. To the northwest of Petaluma the land rises gently to the fertile alluvial lands of Santa Rosa Valley and similarly beyond Alviso at the southeast is found the larger Santa Clara Valley. To the westward of the bay, the mountain ridge separating the valley from the ocean rises to over twenty-six hundred feet in Mount Tamalpais, ten miles northwest of the Golden Gate, while to the southward of the Golden Gate, opposite Santa Clara Valley, the Santa Cruz Mountains reach a height of over three thousand feet. Eastward of the bay, the ridges of the main Coast Ranges rise abruptly, the more distant peaks being higher than those on the west. Because of peculiarities of local surface drainage, the term Valley of the Bay of San Francisco is frequently restricted to the limits just indicated, but in reality the area described is merely the central depression of one of the three major longitudinal valleys of the Coast Ranges. While it is true that the northern and the southern ends of this larger valley are drained by rivers which do not empty into the bay, their basins are separated from the central depression merely by slight, almost imperceptible, elevations in the main valley floor, not by structural ridges. As topographic maps are not yet available for the major part of the Coast Ranges a photograph of a sketch model is reproduced in plate 13 to show the general topography of the

valley of the Bay of San Francisco. Local features are somewhat emphasized to represent the smaller passes on the scale of the model.

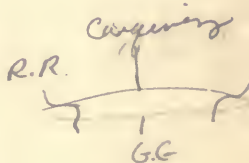
The relation of the main valley to the other valleys involves some consideration of the structure of the Coast Ranges. While their geological history is extremely complex, the present topography is relatively simple if considered only in its broader outlines. The Coast Ranges are generally described as a series of ridges roughly parallel both to the coast line and to the trend of the great interior valley of California. In more exact study it is recognized that the ridges not only vary slightly from parallelism, but that they frequently run together and coalesce. In consequence travel can not take place around the ends of the ridges, but must be over the intervening ranges in going from one valley to another. Passes, however short, transverse to the general NW-SE trend of the Coast Ranges are so unusual as to challenge investigation; in fact, for those familiar with the region the chief interest in the subject of this paper lies in the existence of so many cross-valleys in such a relatively short distance. The generalization asserting the parallelism of the ranges to the California Coast line must also be modified, the ridges of the Coast Ranges showing a marked, though by no means invariable tendency to cross obliquely from the Great Valley of the interior to the sea. In consequence of this direction of structural lines some of the valleys of the Coast Ranges open obliquely to the ocean. Of the three major valleys of the Coast Ranges two are of this type. The Salinas Valley in the southern half of the province heading against the western wall of the San Joaquin Valley opposite Bakersfield, opens to the coast at Monterey Bay. To the northward of San Francisco the Eel River has its headwaters on the westward slope of the range limiting the Sacramento Valley, and flowing obliquely across the Coast Ranges, empties into the ocean a few miles south of Eureka. Midway between these two valleys which open normally to the sea is the valley of the Bay of San Francisco, which has no structural outlet to the ocean, the Golden Gate being primarily an erosional opening. This valley is the longest within the Coast Ranges, but its three separate drainage systems and the various local names

of its sub-valleys have prevented the general popular recognition of its extent or even of its existence as essentially a unit depression. The extent of the valley from the head of the Russian River southeasterly through Santa Rosa Valley, San Francisco Bay and Santa Clara Valley to the source of the San Benito River is approximately 260 miles. The length of the entire valley is thus equivalent to that of the San Joaquin, but the alluvial floor is generally narrow, its extreme width of scarcely twenty miles occurring in Santa Clara County.

The waters of San Francisco Bay occupy the central and lowest part of this long valley, and it naturally would be expected that here should be the converging point for all the drainage, but the facts are not in accord with this supposition. The Russian River, as has elsewhere been described,¹ flows toward the bay for the greater part of its course, and then making an abrupt turn, cañons through the western highland to the ocean. It is a marked coincidence that to the southward the San Benito River, flowing northward toward the bay, also turns abruptly westward through a narrow gorge to the ocean. Because of the peculiar course of these rivers, the central portion of the valley of the Bay of San Francisco receives relatively little drainage from the Coast Ranges, but the major run-off of the state, the combined flow of the Sacramento and the San Joaquin river systems, enters the bay from the east by the gorge of Carquinez Straits, and leaves on the west through the Golden Gate—the submerged cañon which in a former cycle was the mouth of the Sacramento River.

In other words, the valley of the Bay of San Francisco is a long and narrow canoe-shaped depression, with the flood of the interior waters of the state pouring transversely across the middle through narrow breaks in the sides, while from either end of the canoe streams flow well toward the center, only to escape to the ocean through openings in the western rim, openings which are not in conformity with the present topography. Both of these openings are considered in this paper, as both offer low passes between valley and ocean.

¹ Holway, R. S., "The Russian River, a characteristic stream of the California Coast Range," Univ. Calif. Publ. Geog., vol. 1, pp. 1-60, 1913.



The five openings which might function as additional entrances to San Francisco Bay, with a subsidence of only 250 feet, are Merced Valley, seven to eight miles south of the Golden Gate, Elk Valley, about four miles north of the Golden Gate, Lagoon Pass and Liberty Gap, the one just south and the other just north of Petaluma, already mentioned as the tidewater city at the northwestern extremity of the present bay, and most northern of all the gorge of the lower Russian River, opening westward from Santa Rosa Valley. The sixth valley, Pajaro Cañon, the gorge furnishing an outlet for San Benito River, needs a subsidence of over (350) feet to be filled by salt water.

In attempting to classify these cross-valleys by origin it is convenient to recall that theoretically they may be (1) either purely erosional, belonging to the present or inherited from a past geographical cycle, (2) purely constructional or diastrophic, or (3) erosional valleys developed along lines of structural weakness. Although the drainage of the Coast Ranges has usually been described as largely subsequent in nature, structural valleys following the same trend as the ranges have been recognized by geologists, but, so far as known to the writer, there is no record of a valley transverse to the trend of the Coast Ranges and primarily structural in development. Very probably there are cases where erosion along fault lines approximately transverse to the prevailing NW-SE trend of structural lines accounts for existing valleys. The Golden Gate and Carquinez Strait may very possibly owe their exact location to such fault lines, the erosional valleys later developed having been drowned by relatively recent depression.

ELK VALLEY

Of the several valleys which a further submergence of this region to the extent of an additional two hundred and fifty feet would convert into entrances to San Francisco Bay the nearest to the Golden Gate is Elk Valley. In many ways it is the most striking of the cross-valleys to be considered. Located less than four miles to the northwest of the Golden Gate, its length of a little more than three miles is approximately the same as that of the valley which it roughly parallels in direction. Both

valleys are incised in rather rugged topography. Elk Valley may almost be termed a gorge, for on either side the hills rise to over a thousand feet in elevation within a mile. In the same distance from the Golden Gate an elevation of 960 feet is reached in a single peak on the north, while southward over two miles must be traversed before an elevation of 400 feet is attained. Even were the water withdrawn from the Golden Gate, the average elevations from the two valley floors would still be somewhat higher for Elk Valley than for the former. In slope, the northern wall of the Golden Gate is steeper than any portion of the sides of Elk Valley except its extreme westward end.

The topography between the two valleys is also greatly diversified. Midway in this small area the grade of a little streamlet flowing into Rodeo Lagoon is so low that its one hundred-foot contour is over a mile and a half from the sea, and yet on the rim of its basin five peaks slightly exceed or closely approach 1000 feet in height. To the northward, the western peak of Mount Tamalpais rises to 2604 feet within six miles of Elk Valley. In fact, marked relief is characteristic of the Coast Ranges for fully thirty miles from the Golden Gate. The Tamalpais highland, which has steep and almost precipitous slopes on both the southwest and the northeast, descends toward the northward to form the low belt extending from Santa Rosa Valley to the ocean near the mouth of Tomales Bay. The southern part of this highland ends abruptly, standing "knee deep" in San Francisco Bay, the water invading the valleys and converting the ridges into peninsulas and islands. The most western and most rugged of these peninsulas is the one cut by Elk Valley.

The present drainage of this valley should now be considered. Approximately midway from bay to ocean the valley floor rises to a height of 190 feet, forming a water-parting from which, during the rainy season, streams flow in opposite directions. Despite the fact that this divide exists midway in the valley floor, Elk Valley is essentially a unit, as can be seen in plate 14, where figure 1 shows the valley looking from the ocean toward the divide and figure 2 the view from the bay end. In both cases one sees beyond the 190-foot water-parting of the main valley bottom.

The valley as a whole seems to bear no genetic relationship to the little intermittent streams occupying its two halves. While with sufficient time they might have cut the lower portions of their valleys, there is no suggestion in the topography that these

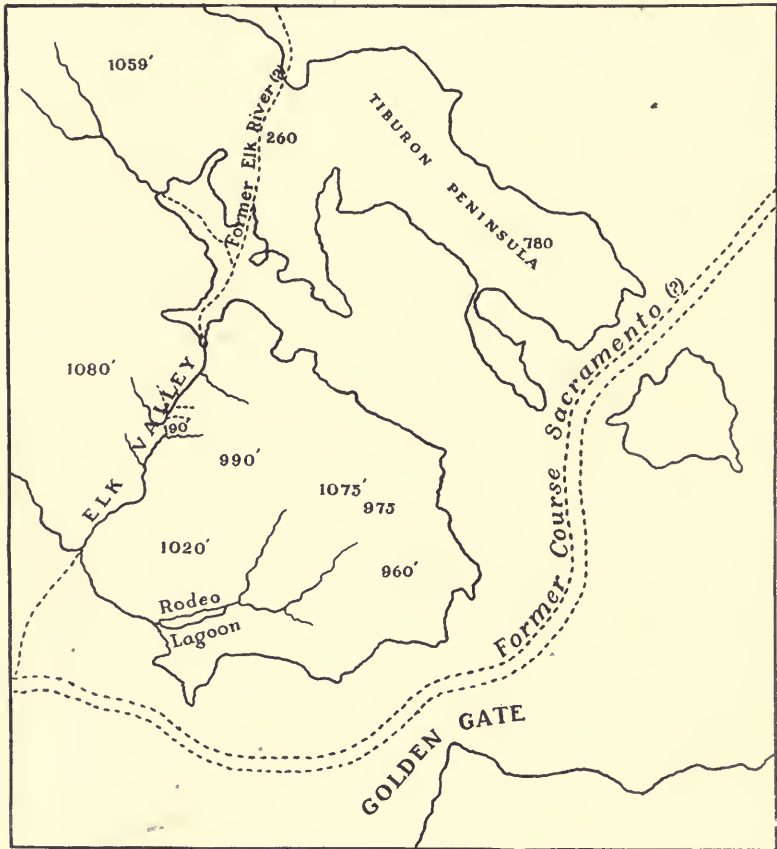


Figure 1

Sketch map showing peculiar drainage of Elk Valley. Dotted lines indicate the probable main drainage channels of a period preceding the faulting and subsidence which have established the present topography.

opposing streams could have lowered the divide between them and widened the resulting col to accordance with the rest of the valley. Other opposing streams both to the north and to the south have been unable to lower to any unusual extent the

crest line of the main ridge. In figure 1 is shown the drainage of Elk Valley as represented on the U. S. Topographic sheets—dotted lines being added to show the direction of side gorges not having streams of sufficient size to appear on the map. It will be noticed that the headwater rivulets of the two opposing streams of Elk Valley start on opposite sides of that gorge, and furthermore that these rivulets occupy ravines which open seaward into the main valley, as if both were tributaries to a west-flowing stream. The branch from the north on reaching the valley floor makes a turn away from the ocean of over 110 degrees and then flows northeastward to the bay; while the branch on the south bends but slightly to the southwest and continues to the ocean. The two streamlets pass within one-eighth of a mile of each other in the flat alluvial field in which lies the 190-foot divide at the center of Elk Valley. In the first half mile eastward of the divide the tributary gullies of the bay stream open oceanward as does the headwater ravine, and hence these small water-courses bend more than a right angle to flow toward the bay.

The suggestion is obvious that the entire Elk Valley is but part of the trunk of a former westward flowing river and that the present bay stream must have been reversed in direction by tilting. The uplift evidently was greater on the west, since the more youthful portion of Elk Valley today is at the mouth of the ocean-flowing stream. This is quite a general characteristic of streams in the northern coast ranges,² and will be considered further in connection with some of the other passes to be described.

Naturally the question arises whether any other traces may be found of the old river supposed to have formed Elk Valley. Seaward the extensive deposits of the tidal delta of the Golden Gate have made impossible the detection of any submerged valleys, had they ever existed. However, the possibility certainly exists that Elk Valley is a fragment of a tributary of the Sacramento when the land stood higher and the mouth of that river was some distance westward, nearer the edge of the continental shelf. To the landward Elk Valley opens into the tidal marshes

² Lawson, A. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, p. 252-3, 1895; Fairbanks, H. W., Bull. Am. Bureau Geog., vol. 2, p. 351, 1901.

and drowned inlets of the bay. Crossing this depressed area and bearing somewhat more to the northward there is found a low gap of 260 feet across Tiburon Peninsula—a gap separating elevations of from 500 to 700 feet from the still greater heights on the slopes of Mount Tamalpais. In the absence of definite signs of the old stream-courses it can only be said that the elevations make this a probable extension of the former river.

In conclusion it may be stated that Elk Valley is an erosional opening through the western ridge of the Coast Ranges, and that it is evidently a portion of the trench of an old stream cut off from the remainder by the diastrophic movements which brought the present bay into existence.

LAGOON PASS

Lagoon Pass crosses the northern edge of the Mount Tamalpais highland and is the longest of the low valleys connecting the bay with the ocean.³ Its entire length following the meanders is fully twenty-five miles from salt water to salt water. In genesis the pass is most closely related to Elk Valley, the shortest of these entrances, for, like the latter, it has undoubtedly developed from the trench of a river belonging to a former geographic cycle.

The bay entrance to the valley begins at the mouth of San Antonio Creek, which empties into Petaluma Creek about six miles southeast of Petaluma. Going westerly up this stream some twelve miles, the divide between bay and ocean is found crossing from left to right the valley floor shown in plate 15, figure 1. Just before reaching this divide and at practically the same level the head of San Antonio Creek is found in a shallow lagoon which is generally dry during the summer. Just beyond the divide in a little side valley to the north there is a larger lagoon from which the water flows westward to the Pacific in a stream called Walker Creek. The field between the two lagoons, in which lies the water-parting, is so nearly level that

³ Lagoon Pass really opens into Tomales Bay instead of directly into the ocean. As "the bay" in this paper usually means San Francisco Bay, the western end of the valley of Lagoon Pass will be spoken of as the ocean end, to avoid the confusion which might result to readers not familiar with local names.

according to the reports of residents the rivulets of the rainy season flow toward the bay or toward the ocean, according to the irregularities of the last plowing. An examination of this field between the lagoons shows that it is a flat alluvial fan built out by a little tributary from the south toward the northern wall of the pass and leaving a slight linear depression from which during heavy rains water flows both to the ocean and to the bay, thus affording free passage for those species of fish which run to the headwaters of streams. The elevation of the alluvial flat between the lagoons is 225 feet, as determined by aneroid barometer—a very low height when it is considered that the distance either westward to the ocean or eastward to the bay is about twelve miles.

The topography bordering this twenty-five mile valley reveals something of its past history. The hilltops near the lagoons range in elevation from five hundred feet on one side to a thousand feet on the other, the height of the Tamalpais highland falling rapidly toward the northward in this vicinity. The character of the valley throughout its course varies in a striking way. The middle portion is mature—the rather narrow flat at the divide in plate 15, figure 1 widening greatly either eastward or westward. At both bay and ocean the valley ends in gorges of very youthful aspect. The western end, lower Walker Creek, is cut to sea-level in a rather even-topped highland ranging from 400 to 800 feet in elevation. The steep sides of Walker Creek descend from grain fields having in general a gentle rolling topography with an occasional higher knoll. An area well advanced in an erosion cycle apparently has been uplifted long enough for the main stream to reach base level, but not long enough for it to widen its channel materially. A narrow flood-plain extending two or three miles from salt water is very plainly not due to lateral corrasion of the stream, but to aggradation resulting from slight recent subsidence.

Lower Walker Creek, although deeply entrenched in a highland, has very pronounced meanders, a rather common characteristic of streams in this vicinity. As stated elsewhere in discussing the Russian River,⁴ the hypothesis that these entrenched

⁴ Univ. Calif. Publ. Geog., vol. 1, pp. 27-28, 1913.

meanders are derived from the meanders of a stream in a base-leveled plain seems a satisfactory one, but should not be regarded as necessary in all cases. In Walker Creek we have apparently an ideal illustration of a stream meandering on the seaward border of an old peneplain later becoming entrenched without displacement during uplift. In this case the uplift is apparently the tilting of a block, the westward edge fronting the San Andreas Fault, along which horizontal movement took place in 1906. In plate 15, figure 2, is shown a view rather typical of lower Walker Creek in the last six or seven miles of its course. The flattened end of the spur in the foreground is somewhat exceptional, but there is other evidence in nearby sea terraces indicating that this portion of the Coast Ranges was uplifted not continuously, but by a series of movements, although they are not commonly registered in small streams. In the flat hilltop in the left of the view is given a suggestion of the mature highland in which the gorge is cut. The photographs reproduced in plate 16 will help one to visualize the topography. Both views are within a mile of the mouth of Walker Creek, the gorge of which crosses the middle distance from right to left about six hundred feet below the grain fields in figure 1, while figure 2 shows the gorge itself, the line of sight being at right angles to that of the previous view and the grain fields of the former being found on the flat top of the ridge in the left of the latter view.

Turning now to the eastern half of the valley of Lagoon Pass, San Antonio Creek, as has been already stated, is also very youthful in its lower course. At the mouth its gorge is cut in hills which rise abruptly six hundred feet above the tidal flats of Petaluma Creek. In general the topography adjacent to San Antonio Creek should probably be characterized as a dissected highland, although it is more varied in relief than that around Walker Creek. Speaking in terms of the assumed previous peneplanation of this region, the portion around Walker Creek must have been more nearly reduced to base-level than that adjacent to San Antonio. In plate 17, figure 1, the view is taken looking downstream from a point two or three miles below the head of San Antonio Creek. With no other knowledge than that gained by observation from this viewpoint, the conclusion would be war-

ranted that the view was taken looking upstream rather than downstream. In fact, going eastward from the viewpoint the flat portions of the floor actually do rise for some distance, San Antonio Creek flowing in "anaclinal" style against the slope of the old valley floor in a trench incised below its level. In plate 17, figure 2, is shown a view looking across the valley floor, showing in the foreground the present San Antonio Valley sloping to the bay, while above may be seen fragments of a graded surface sloping to the right, or westward, to the ocean. The preceding description has been couched in terms which have already suggested the writer's hypothesis as to the genesis of

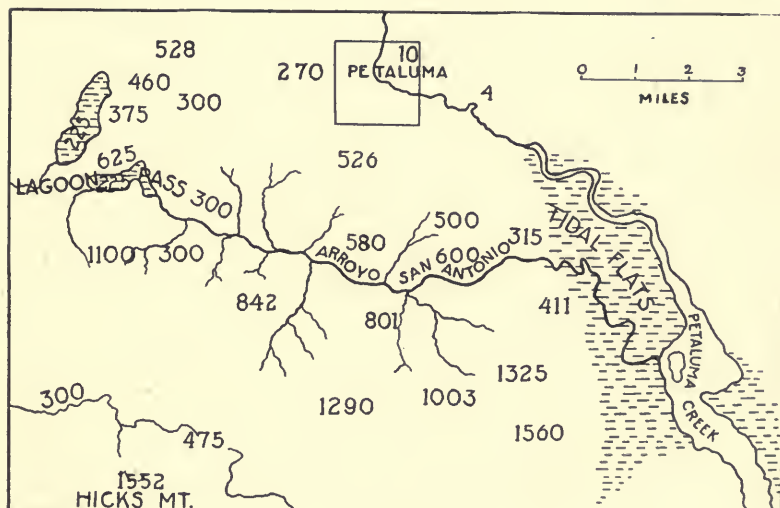


Figure 2

Sketch map showing drainage pattern of San Antonio Creek—the eastward-flowing stream of Lagoon Pass. Elevations and drainage from the advance sheets of the Petaluma quadrangle furnished by the courtesy of the Director of the United States Geological Survey.

the valley. An old westward-flowing stream seems to have headed somewhat to the eastward of the lagoons near the present divide. The topography near the bay shows in the reconnaissance work so far done no remnants of the trunk channel of a former stream, but some westward-pointing tributaries (see fig. 2) have been

found which ultimately flow to the bay, indicating reversed drainage similar to that in Elk Valley. The mouth of San Antonio Creek is, then, a new gorge developed during, and as the result of, recent diastrophic changes. The process by which this was done does not seem entirely clear. From the Golden Gate to Petaluma the Mount Tamalpais highland meets the bay in a fairly bold front, with slopes so steep in most places as to suggest recent folding or faulting. The areal geology of this region is not yet published and there is no reliable map for the details of drainage. In the present state of the investigation the hypothesis which accords best with the known facts may be stated as follows: In the movements following a former period of partial base-leveling a block reaching from near the present Petaluma Creek to the San Antonio fault near the ocean was slowly uplifted, the greater uplift being on the west. The old westward-flowing river extending nearly the full length of this block persisted, the rejuvenated stream cutting near the ocean the youthful gorge of the present Walker Creek. In the middle portions of the old river the grade was lessened and the river even ponded near the present lagoons, causing sedimentation. In the meantime on the extreme edge of the block some small stream rejuvenated by uplift rapidly pushed its divide westward by headward erosion; rapidly, for in competition there was the sluggish headwater portion of the old river ponded by tilting toward the bay. Under these circumstances the bay stream pushed westward its headwater gully, finding in the trench of the old west-flowing river its best location. Meanwhile near the lagoons ponding had produced such extensive sedimentation that portions of the flood-plains finally established by the old west-flowing river still remain, although the drainage is now eastward to the bay. The hypothesis may be said to involve the formation of a syncline in the old erosion surface near the present lagoons.

The outcropping rocks in the vicinity belong to an old series (Franciscan) upon which the later rocks of the Coast Ranges have been deposited, and have been so much folded and faulted that there is no possibility of getting any stratigraphic evidence of recent folding. To the northeastward Santa Rosa Valley is

a synclinal fold in late rocks, according to Osmont,⁵ who has also shown in a section fifteen miles to the northwest of the lagoons a syncline, the axis of which, if it follows the prevailing structural trend of the Coast Ranges, would pass through the lagoons. This strengthens the topographic evidence of depression afforded by the recent sedimentation in the vicinity—sedimentation for which it is otherwise difficult to account. According to the foregoing, Lagoon Pass, in spite of its much greater length, is to be classed with Elk Valley in genesis as being developed from a valley inherited from a former geographic cycle.

LIBERTY GAP

The next opening from the bay valley to the ocean is about six miles north of Lagoon Pass and over thirty miles from the Golden Gate. Liberty Gap, naming it from the schoolhouse near the water-parting, is genetically different from the two passes already considered. It is not a narrow opening cut below the adjacent levels, but is the broad, low belt already mentioned, made by the downward pitching of the general level of the Tamalpais highland. The topography has the slight relief and gentle slopes of age (pl. 18, fig. 1). The low hills, seldom more than four hundred feet above the sea, are monadnocks, the harder rocks frequently outcropping. The region is evidently a portion of an old erosion surface lying approximately at the level at which it developed and presumably forms part of the old peneplain, fragments of which various writers on the physiography of the state have noted at elevations ranging from one thousand to four thousand feet or even more. The portion here described is exceptional in being so nearly at its original level of peneplanation. Northward the old surface rises again and, traced by the general accordance in level of the flat tops of the hills, it can be carried across the gorge of the lower Russian River to the highlands of the Mendocino Plateau. Southward in like manner the old surface is carried on the hilltops bordering Lagoon Pass and traces of it are found around Mount Tamalpais. To the east of Liberty Gap the old surface is presumably found below

⁵ Osmont, Vance C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 4, pl. 7, 1905.

the alluvial deposits of Santa Rosa Valley and to the southeast monadnock-like hills project in places out of the marshes bordering Petaluma Creek. Still farther to the southeast across shallow San Pablo Bay there are many indications that the old surface may again be identified in the lowlands bordering the San Francisco Bay along the northern extension of the Berkeley Hills.

Returning to the specific question of a low-lying connection between the bay valley and the ocean, the water-parting between the two is found on this old surface quite close to Santa Rosa Valley. The lowest point in Liberty Gap is about six miles northwest of Petaluma, where the elevation is but 150 feet, checking the aneroid barometer by readings on known stations along the nearby Petaluma and Santa Rosa Railroad. While the water flows from this point westward some twelve miles to the ocean, the general level of the old erosion surface rises, reaching its greatest height close to the seashore. Here are some of the largest areas of quite flat land, the low plateau ending abruptly at levels some six to seven hundred feet above the sea. In this plateau the west-flowing streams have cut narrow cañons which, like the cañon of Lower Walker Creek, have been modified by the accident of slight recent subsidence. In this vicinity the lower portions of the channels are still narrow lagoons not yet filled by sediment. In plate 18, figure 2, the view was taken between two and three miles from the ocean, looking westward at the Estero San Antonio, one branch of which heads at the 150-foot point in Liberty Gap. The narrow lagoon is largely tidal water. The meanders are similar to those described in Walnut Creek, but are not so deeply incised. The hills in the distant center are near the ocean and have quite extensive flat fields not visible from the low viewpoint. The next creek northward shows a similar but larger lagoon at its mouth. Both small streams are extreme instances of the abnormality mentioned as common to coast streams in this region, namely, in having youthful valleys at their mouths and older forms toward their headwaters. Both have their headwaters to the eastward in the old topography near the low divide on the border of Santa Rosa Valley and both have their widest valley floors and most gentle slopes in their

middle courses. A typical view is given in figure 19, plate 1, which is taken almost exactly half way from divide to ocean, looking across the valley opening into the Estero San Antonio. The lowest level in the center of the valley at the left is under one hundred feet. The bare outcrop on the right and the gentle slopes of the distant hills, which probably are less than three hundred feet in elevation, are characteristic of the low belt of Liberty Gap.

Some interesting topography bearing on the physiographic development of the region westward of both Lagoon Pass and Liberty Gap is shown in plate 19, figure 2. In the foreground is seen the flat aggraded floor of a little tributary which enters Walker Creek near its mouth. This valley floor where the cattle are now grazing was formerly the tidewater port for the little town of Tomales, the scattered houses seen in the distance being part of that village. Tomales about 1860 developed into a farming center, shipping potatoes to the young city of San Francisco. The inlet then, at least at high tide, had enough water for schooners and for a small steamer to bring lighters from the deep water. The harbor was given up about 1875 because of the building of the railroad and because the cultivation of the former grass-covered slopes had resulted in rapid erosion and in correspondingly rapid deposition, which has now converted the former harbor into a meadow. The topography in figure 2 is also interesting because it shows how the elevation of the old surface seen around Walker Creek in figure 2, plate 15, becomes rapidly lower in going northward from Lagoon Pass toward the region westward of Liberty Gap.

Briefly summarizing, that the special importance of Liberty Gap in the present paper may not be lost in the related physiographic detail, this particular potential entrance to the valley of San Francisco Bay owes its existence to two facts: First, it is situated on a low-lying portion of the old peneplain of the Coast Ranges, and secondly, it is connected with the ocean by the incised gorges of streams which have persisted against the landward tilting of a block, the uplifted edge of which is at the present coast line.

RUSSIAN RIVER GORGE

The most northern of the entrances to San Francisco Bay which would result from the supposed further depression is the gorge through which the Russian River flows in the last twenty miles of its course. The writer has recently discussed this stream in considerable detail,⁶ and only the briefest resumé of the portion concerning the gorge will be made here as an introduction to a consideration of its relation to the other cross-valleys described.

The lower Russian River is the remnant of an old consequent stream which existed at the close of the period of peneplanation in the Coast Ranges. Slow uplift has deeply entrenched this portion of the river, but the region to the eastward has had a long history of depression, deposition and changes of level which have resulted today in the low-lying alluvial Santa Rosa Valley to the northward of the present San Francisco Bay. As said in the introduction, the Russian River flows southeasterly from the northwestern end of the canoe-shaped valley of the bay of San Francisco, until it reaches the portion locally called the Santa Rosa Valley, and then, although there is no ridge separating it from the waters of the bay, it turns westward, flowing through twenty miles of gorge to the ocean. The height of the indefinite water-parting between the river and the bay reaches its maximum of 113 feet in the grain fields ten miles to the northward of Petaluma. A subsidence of 250 feet would thus extend the bay northward over Santa Rosa Valley beyond the town of Healdsburg and make the gorge of the Russian River a salt-water estuary 200 feet and more in depth, with over 130 feet for the shallowest water between it and the present bay. The Russian River entrance to the enlarged San Francisco Bay is, then, in genetic history similar to that commonly accepted for the Golden Gate, the difference being that the Russian River is a small stream, while the Sacramento River, the old mouth of which has become the Golden Gate, is the major river of the state.

Of all the potential entrances to the bay Russian River Gorge and Liberty Gap have the lowest divides separating them from the present level of the bay. Liberty Gap in particular is also

⁶ Univ. Calif. Publ. Geog., vol. 1, pp. 1-60, 1913.

in a region of lower general relief than that bordering the Golden Gate and is no more distant than is the latter from Carquinez Strait, through which the Sacramento reaches the bay valley. Considering these relations, the question why the present entrance is cut close to Mount Tamalpais at the Golden Gate rather than through the open country near Liberty Gap invites speculation. The presumption is that, when the bay region was at its lowest state of degradation in the previous geographic cycle, the course of the Sacramento was fixed, its mouth being at the present Golden Gate and that subsequent uplift was so slow that the river uninterruptedly maintained its course. If elevation had been faster for a period than the downward cutting of the river, ponding would have resulted, with overflow through the lowest available channel to the ocean. So long as ponding did not take place, if other possible openings were separated from the river by divides barely above the highest floods, the persistence of the course through the Golden Gate was as well assured by low barriers as by mountain ridges.

This speculation as to the rather simple factors controlling the course of a river during uplift is offered not only as part of the discussion of the problems of this paper, but also in connection with the past discussion as to the former outlet of the Sacramento having been southward through Santa Clara Valley into Monterey Bay—an hypothesis which will be considered further in the description of Pajaro Cañon.

MERCED VALLEY

The two remaining valleys of the six enumerated for discussion lie to the southward of the Golden Gate and both have been discussed in geological literature, but not from the standpoint of this paper. Professor Lawson named Merced Valley and included it in his general description of the topography of San Francisco Peninsula.⁷

Merced Valley is from seven to ten miles south of the Golden Gate and is entirely distinct in character from the other valleys described. They have a direction roughly at right angles to the

⁷ Sketch of the Geology of San Francisco Peninsula, 15th An. Rep. 1893-94, U. S. G. S., pp. 405-476.

trend of prevailing structural lines and in origin are primarily erosional. Merced Valley extends NW-SE in harmony with the trend of the main ridges and valleys of the coast and in origin is structural. Its southwestern slope carries recent marine deposits which are folded down beneath the valley floor and abut against the uplifted fault block of San Bruno Mountains on the northeast. Figure 1 of plate 20 is a view looking down on a model of San Francisco Peninsula, and shows Merced Valley extending northwesterly from the bay to the ocean, a distance of some eight miles. The highest point in the pass is about 190 feet. Both ends of the valley are occupied by intermittent streams and both bear topographic evidence of recent submergence. Although structurally Merced Valley would seem to be a natural outlet for Santa Clara and San Benito valleys, there is no evidence that it has ever functioned as a drainage channel for their waters during the present geographic cycle.

PAJARO CAÑON

In the geological literature of the past this cañon has figured, not as an unfinished entrance to San Francisco Bay, but rather as a discarded outlet for its waters. Professor Joseph LeConte advanced the theory that the Sacramento River formerly flowed southward through the valley of the bay of San Francisco to Pajaro Cañon and thence to Monterey Bay.⁸ His basal assumption postulates an elevation of the land during Pliocene time of some 2000 to 2500 feet more than at present, with the shore line consequently much farther to the west and the river valleys correspondingly extended on the continental shelf. He then argues that, as there is no submarine valley off the Golden Gate and as there is a well-defined one in Monterey Bay, the Sacramento must have flowed southward in the valley of the bay of San Francisco and thence to Monterey Bay. That is, he considers the Golden Gate a recent opening which has been made by an uplift shutting the Sacramento off from its first outlet into Monterey Bay. He gives no consideration to the probability that any submerged channel off the Golden Gate would have been fully obliterated by the extensive deposits of the tidal delta since

⁸ Bull. Geol. Soc. Am., vol. 2 (1891), p. 326.

formed, nor to the probability that with the land at a higher elevation than the present the combined drainage of the Salinas and San Benito rivers might be fully competent to cut the submerged cañon found in Monterey Bay. These two considerations, together with the further fact that the narrow Pajaro Cañon shows no signs of having been occupied by a river the size of the Sacramento, seem to the writer to render extremely improbable the theory advanced by Professor LeConte—a theory for which he himself states the main object “is to direct attention and stimulate investigation.” Other objections to Professor LeConte’s theory, based on the height of the present divide between San Francisco and Monterey bays compared to the heights of the divides between San Francisco Bay and the ocean, have recently been considered⁹ by Professor J. C. Branner of Stanford University, although he does not mention the three passes which lie to the north of Elk Valley. Dr. Branner calls attention to the fact that the water-parting separating the present San Francisco Bay from Monterey Bay is 345 feet instead of less than one hundred feet, as quoted by Professor LeConte, and that with the higher elevation the closing of the Golden Gate would cause overflow to the ocean at other low places before the water would escape southward through Pajaro Cañon. This is evident *provided the elevations in the past had the same relative height as in the present*. The latter proviso seems very doubtful if the topography has evolved according to Professor LeConte’s theory, which is based on the supposition that an orogenic depression of over two thousand feet has taken place since the period he fixes for the drainage of the Sacramento through Pajaro Cañon. In a general change of two thousand feet elevation for the bay region as a whole it is very probable that the relative elevations of passes and ridges were greatly changed.

The writer is in entire agreement with Dr. Branner’s conclusion that “the theory of the postglacial age of the Golden Gate does not appear tenable,” although the opinion is based upon somewhat different considerations. The broader conclusion offered from the results of the present investigation is that there

⁹ The Drainage of Santa Clara Valley, Jour. of Geology, vol. 15 (1907), pp. 1-10.

is no physiographic evidence that any of the six openings in addition to the Golden Gate between the valley of the Bay of San Francisco and the ocean have ever functioned as outlets for the Sacramento River during the present geographic cycle, extending that period sufficiently to include the faulting and folding since the last marked peneplanation. Pajaro Cañon in this paper takes its place as an opening which with uniform depression of over 345 feet would for the first time afford a salt-water connection from the present San Francisco Bay to the ocean. Genetically it seems to be the southern correlative of the Russian River in its relation to the valley of the Bay of San Francisco. Its gorge is shorter and does not maintain its rugged character clear to seacoast. The longest tributary of Pajaro River is the San Benito, which, although differently named, probably should be considered the trunk stream. The San Benito-Pajaro drainage basin has many problems which invite detailed study.

PHYSIOGRAPHIC CHANGES AND FAUNAL RELATIONSHIPS

The diastrophic changes which have led to the development of the present topography in the bay region have evidently resulted in many accidents to the drainage systems occupying that area. These changes are not to be thought of as necessarily belonging to a remote past. The writer has described the transfer of a tributary of the Russian River to the Sacramento drainage by a landslide so recent that its form and its track are still plainly recognizable.¹⁰ In this portion of the Pacific Coast there is not lacking evidence that folding and faulting may even now be causing slow changes in level sufficiently great to affect delicately adjusted drainage systems. In addition it is well accepted that ordinary processes of stream erosion or of deposition may make changes in the boundaries of drainage systems. Reversing of streams and transference of tributaries must be now and must in the past have been likely to be accompanied by changes in the fluvial faunas of the region. Some notes on the connection between physiographic changes and faunal problems in the Coast Region have already been published. The change in the Russian

¹⁰ *Science*, N. S., vol. 26 (1907), p. 382.

River drainage referred to above has been commented on by Professor Snyder of the Department of Zoology of Stanford University, who has pronounced the physiographic change in the instance reported as immaterial to the biologist because the Sacramento River has a larger fauna which includes the strictly fluvial species of the Russian River, and that hence any number of changes in that direction would produce no changes in faunal groups. The present study has added some knowledge of drainage changes and drainage connections in the central Coast Ranges of California which seem to bear on faunal relationship. To show the possible importance of these changes there is added the following brief statement of some of the problems in this vicinity from the standpoint of the biologist.

Notes on Faunal Problems of Russian River and Tributaries of Tomales and San Pablo Bays, by Professor J. O. Snyder, Department of Zoology, Stanford University.*

The fish fauna of the Russian River is much like that of the Sacramento-San Joaquin system, differing mainly in that it lacks some species that are found there. Besides anadromous forms like the lamprey, *Entosphenus tridentatus*, the trout, *Salmo irideus*, and some other species that are able to pass freely from salt to fresh water as the stickleback, *Gasterosteus cataphractus*, the cottoids or bullheads, *Cottus gulosus*, *C. asper*, and *C. aleuticus*, there are now known to inhabit the Russian River four strictly fluvial species, a sucker, *Catostomus occidentalis*, and three minnows, *Mylopharodon conocephalus*, *Ptychocheilus grandis* and *Rutilus symmetricus*. Only the latter, the strictly fluvial fishes, should be considered in a discussion of the faunal relationships of rivers, for being unable to withstand salt water, they must remain in a system when once they are introduced, their position being analogous to that of reptiles on an oceanic island. These four species of their closely related representatives are of very restricted distribution, occurring only in the Sacramento-San Joaquin system, and in certain coastal streams of central California. All inhabit the larger tributaries of San Francisco Bay. *Catostomus*, *Ptychocheilus*, and *Rutilus* are represented in the streams which enter Monterey Bay, but no farther south, and *Rutilus* occurs in Gualala and Navarro rivers which reach the ocean at points north of the mouth of Russian River. *Catostomus humboldtianus* of Bear, Eel and Mad rivers is apparently a representative of *C. occidentalis* of the Russian and Sacramento rivers. Some of these characteristically Sacramento species have also found their way into the streams that flow into Tomales Bay.

Large series of specimens of these fluvial species from both the Russian and Sacramento rivers, and also from the streams tributary to San

* Private communication to the writer.

Francisco Bay were at one time carefully examined in an attempt to determine whether any slight differences in structure or color might be found between them. None appeared, the fishes differing only as individuals of a species from a given stream might differ among themselves, except in the case of *Rutilus symmetricus*, a small silvery minnow, where a slight amount of differentiation seemed evident. Individuals from Russian River appeared to be slightly more slender, with somewhat longer fins, the whole body being of more trim and elegant proportions. When specimens from Russian River and from Gualala and Navarro rivers were compared it became quite evident that certain small, but measurable differences existed, those from the latter streams having more robust bodies, deeper caudal peduncles, and more rounded and shorter snouts.

To recapitulate: the fauna of the Russian River is essentially that of the Sacramento-San Joaquin in so far as the latter is represented, a slight amount of differentiation possibly appearing. One Russian River species is represented in Gualala and Navarro rivers to the northward, where a marked degree of differentiation has appeared.

When therefore one considers the relationships of the species, and the relative geographic positions of the streams, one is warranted in concluding that the Russian River fauna was derived from the Sacramento-San Joaquin system.

There is another matter of considerable interest in connection with the Russian River and Sacramento fishes. I have stated that the representation of Sacramento-San Joaquin fishes is not complete in the Russian River. There are lacking certain species, *Orthodon microlepidotus*, *Lavinia exilicauda*, *Pogonichthys macrolepidotus* and others, which are abundantly able to maintain themselves in smaller streams, e.g., those tributary to San Francisco Bay. Why are not these found in Russian River? Possibly an answer will present itself when one comes to consider the means by which Sacramento fishes might have reached the Russian River. However, if one finds that at one time the two streams had a main channel connection, I can see no way to account for the absence of these species. If, on the other hand, it becomes apparent that the Russian River received its fauna by some method of stream capture by which only a small part of the upper course of a creek was diverted, there then appears to be an opportunity for a reasonable explanation. For *Orthodon*, *Lavinia*, and *Pogonichthys* are channel fishes, inhabiting the lower courses of the rivers, preferring the deeper and more quiet waters, while *Catostomus*, *Rutilus*, and *Ptychocheilus* closely follow the trout to the headwaters. If my observations on their habits are not at fault it will appear that the chances of the latter fishes for a migration through an upstream connection are much better than those of the channel forms, and if an opportunity were presented for such a migration, or if a small part of a tributary were transferred to another system, the upstream fishes would be more likely to profit by it.

Regarding the fishes of the streams tributary to Tomales Bay: I have found but two fluvial species there, a sucker, *Catostomus occidentalis*, and a minnow, *Rutilus symmetricus*. A detailed examination of many well-preserved specimens of these species and comparisons with specimens

from the Sacramento-San Joaquin river system reveals no important differences. Similarly it was found that no differences appeared when fishes of the Tomales Bay streams were compared with those of Russian River. In so far as they have been observed, the fishes of the tributaries of Tomales Bay are like those of the streams flowing into San Pablo and Suisun bays.

The streams tributary to Tomales Bay are very small, and with the exception of Paper Mill Creek, where both *Catostomus* and *Rutilus* may always be seen, they do not offer very favorable opportunities for the existence of river fishes.

Might it not be possible that an ancient connection occurred between the Sacramento and the Russian River basins, one so long ago that all superficial evidences have disappeared, that a little later a passageway was opened for migration from the Russian River to the Navarro, which was also obliterated, and then more recently fishes were again introduced from the Sacramento at various times and in sufficient numbers to swamp any variation that might have set in among the Russian River fishes? That would account for differentiation in the Navarro, for only one species occurring there, and for the lack of differentiation in Russian River.

While physiographic study in the region covered by Professor Snyder's notes cannot be said to have advanced much beyond the reconnaissance stage as yet, the results already obtained concerning connections, past and present, between the different drainage basins come surprisingly close to the conditions which he has theoretically outlined as solving the biological problems. These results will now be summarized for the three areas mentioned.

RELATION OF RUSSIAN RIVER TO BAY DRAINAGE

The question of present and past connections between the Russian River and the Sacramento River and other streams flowing into the northern portion of San Francisco Bay is quite complex because of the extensive area involved. Assuming, as seems reasonable, that the marsh lands around the northern end of the bay become covered with fresh water during extensive floods from the Sacramento and that consequently strictly fluvial species from that river may reach the streams from Santa Rosa and from Sonoma Valleys, there are two instances where physiographic conditions seem to meet exactly the conditions laid down by Professor Snyder as affording "opportunity for a reasonable

explanation." The first locality is on the western slope of Sonoma Mountain facing Santa Rosa Valley, where the indefinite divide in the valley floor separates Petaluma Creek from Copeland Creek, a tributary of the Russian River. Copeland Creek heads well up on Sonoma Mountain and has built quite an extensive low-grade fan at the point where it debouches upon the valley floor. The fan is noticeably convex to the eye where it is crossed by the county road leading north to Santa Rosa. From the apex of the fan channels lead northward to the Russian River and also southward to San Pablo Bay—channels which when recently visited were separated by a low ridge less than two feet high. Nearby residents assured the writer that in flood time the stream frequently discharged southward to the bay. The conditions for the prevention of the mingling of channel fish "preferring the deeper and more quiet waters" and for permitting passage to the upstream fish from the bay to Russian River seem to meet the requirements set by Professor Snyder.

Sonoma Mountain lies between the alluvial floors of Santa Rosa and Sonoma Valleys. The second opportunity for the mingling of upstream fishes was found in the latter valley. In going northward from San Pablo Bay, Sonoma Valley, instead of narrowing in the conventional way to gorges and ravines lost in encircling hills, gradually changes the slope of its alluvial floor at an elevation of 464 feet just above the railway station at Kenwood, descends toward the northwest, and connects with Santa Rosa Valley. At the highest point in the valley an alluvial fan has been built out a distance of a little over a mile (plate 20, figure 2). The fan is formed by a stream from Hood Mountain on the east. In this case migration of the stream has apparently not occurred within the period of some fifty years since the valley was settled. There is, however, a small channel on the north side leading to Russian River, while the main flow at present is southward to the bay. The latter channel is incised some twelve feet, and a flat slope less than a hundred feet wide separates it from the small northern channel. The fan is occupied as a farm, the apex being well covered with farm buildings and cultivation may have obliterated older channels. From the known habit of streams in building fans it is practically certain

that so long as the fan was being built the stream flowed alternately toward the Russian River and toward San Pablo Bay. That period may be far back historically but it is probably recent compared to time needed for species to change perceptibly.

RELATION OF TOMALES AND SAN PABLO BAYS

The second of the problems referred to by Professor Snyder is at least partially answered by the description already given of Lagoon Pass. Duck-hunters vouch for the fact that the streams flowing east and west from the central divide of that valley are frequently united by standing water joining the two headwater lagoons. In the present topography there does not seem to be opportunity for free intermingling of the various streams flowing into Tomales Bay, as there is no continuous marsh land surrounding it. The bay is, however, very shallow, its twenty-five miles of length affording only one spot where the water is sixty feet in depth. Remembering that Tomales Bay lies along and is undoubtedly causally related to the San Andreas fault zone, it may well be that in comparatively recent times the elevation has been such as to exclude salt water and to unite the tributaries of the bay into one trunk stream. The present connection of Walker Creek and San Antonio Creek is well established, and the possible extension of the connection to all the streams of Tomales Bay by relatively slight changes of level will be granted.

The more detailed study of the migration of streams on alluvial fans and the effect of uplift and depression in uniting coast streams or dismembering drainage systems in their relation to fresh-water fauna has not been attempted because of the excellent discussion of the same problem by Doctor Branner for the streams of Santa Clara Valley and Pajaro River in the paper referred to above.

RELATION OF NAVARRO TO RUSSIAN RIVER

Referring to Professor Snyder's remarks on the fauna of the Navarro River in comparison with that of the Russian and Sacramento rivers, the recent physiographic study of the Rus-

sian River¹¹ already cited indicates a past history remarkably similar to that outlined in his hypothetical question as to the possible physiographic changes which might account for faunal conditions (page 105). The past relations of the Russian and Navarro rivers may be briefly summarized as follows: the Navarro River formerly headed considerably to the eastward of the course of the upper portion of the present Russian River. The notably linear southeast course of the upper Russian River is held to be the work of a subsequent stream which has developed headward along a line of weakness and has successively beheaded various coast streams of the Mendocino Plateau, among others the Navarro. The capture is indicated by the eastern tributaries of this portion of the Russian River flowing northwesterly to join that stream instead of southwesterly as they normally should, and by remnants of the trench of the former Navarro. The period at which this capture occurred is certainly far back in the past and may be sufficiently remote to account for the differentiation of species transferred from the Russian to the Navarro at that time. Previous connection of the Russian and Sacramento drainage may well have been established before the capture, considering the conditions of peneplanation indicated in the study of Liberty Gap. Connection in recent times between the latter rivers seems to be proven beyond a doubt so far as headwater connections passable for upstream fishes are concerned. These later conditions would apparently explain the lack of differentiation today in the fauna of the Russian and Sacramento basins.

¹¹ Univ. Calif. Publ. Geog., vol. 1, pp. 11-13, 1913.

SUMMARY

Including the Golden Gate with the six valleys discussed, they may be classified as follows:

Primarily Developed by Erosional Forces

- | | | |
|--|---|---|
| A. Russian River
Gorge, Golden Gate,
Pajaron Cañon | } | Gorges of the lower courses of rivers which have maintained themselves during uplift. The recent depression drowning the Golden Gate has affected the other two but to a less extent. |
| B. Lagoon Pass,
Elk Valley | } | Remnants of the trenches of old streams which have not maintained their courses during uplift—modified by subsequent erosion of present streams. |
| C. Liberty Gap— | | A low-lying remnant of an old erosion surface. Streams have since cut gorges to the ocean through the uplifted western edge. |

Primarily Developed by Diastrophic Forces.

- | | |
|-------------------|---|
| A. Merced Valley— | A structural valley having the prevailing trend of other structural features of the region. |
|-------------------|---|

Only one of these valleys is now occupied by salt water. The other six are here grouped together because their low elevation makes possible their becoming entrances to an enlarged San Francisco Bay in the event of subsidence of the region during future geological time. The unstudied and topographically unmapped region to the north of Mount Tamalpais may contain other low-lying passes at an elevation not far from that of the divide at present separating San Francisco Bay from Pajaro Cañon.

So far as the facts have yet been determined in the two branches of science carrying on the preliminary investigations, the present and past physiographic relations seem to harmonize reasonably well with the faunal relationships of the fluvial species belonging to the drainage basins in the region of the northern portion of the valley of the Bay of San Francisco.

Transmitted July 25, 1913.

PLATE 12

SAN FRANCISCO BAY AND VICINITY

The lighter blue shows the five additional entrances and the enlargement of San Francisco Bay which would result from a subsidence of the land two hundred and fifty feet below the present level. Boundaries of submerged areas are diagrammatically correct merely.

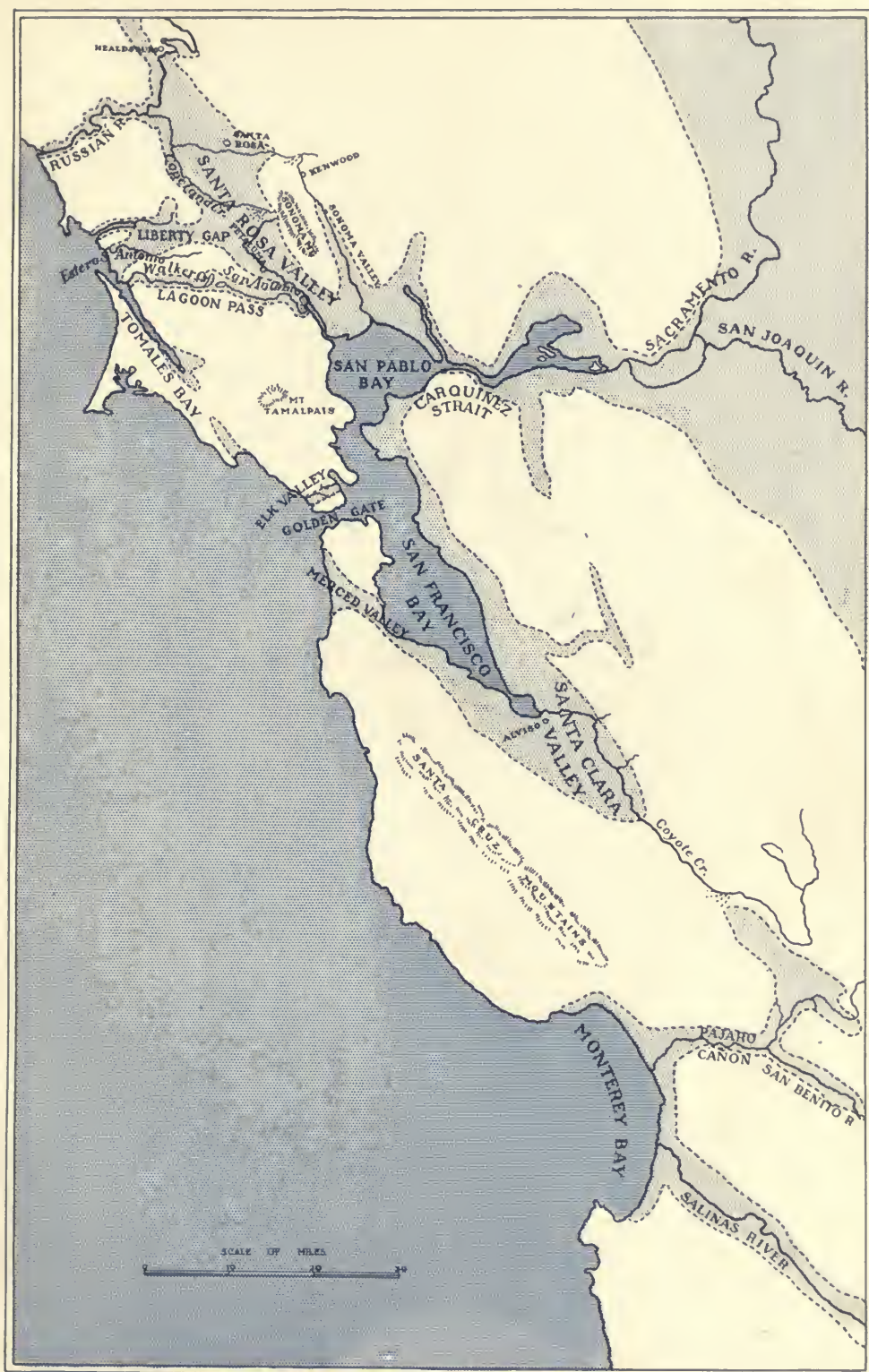


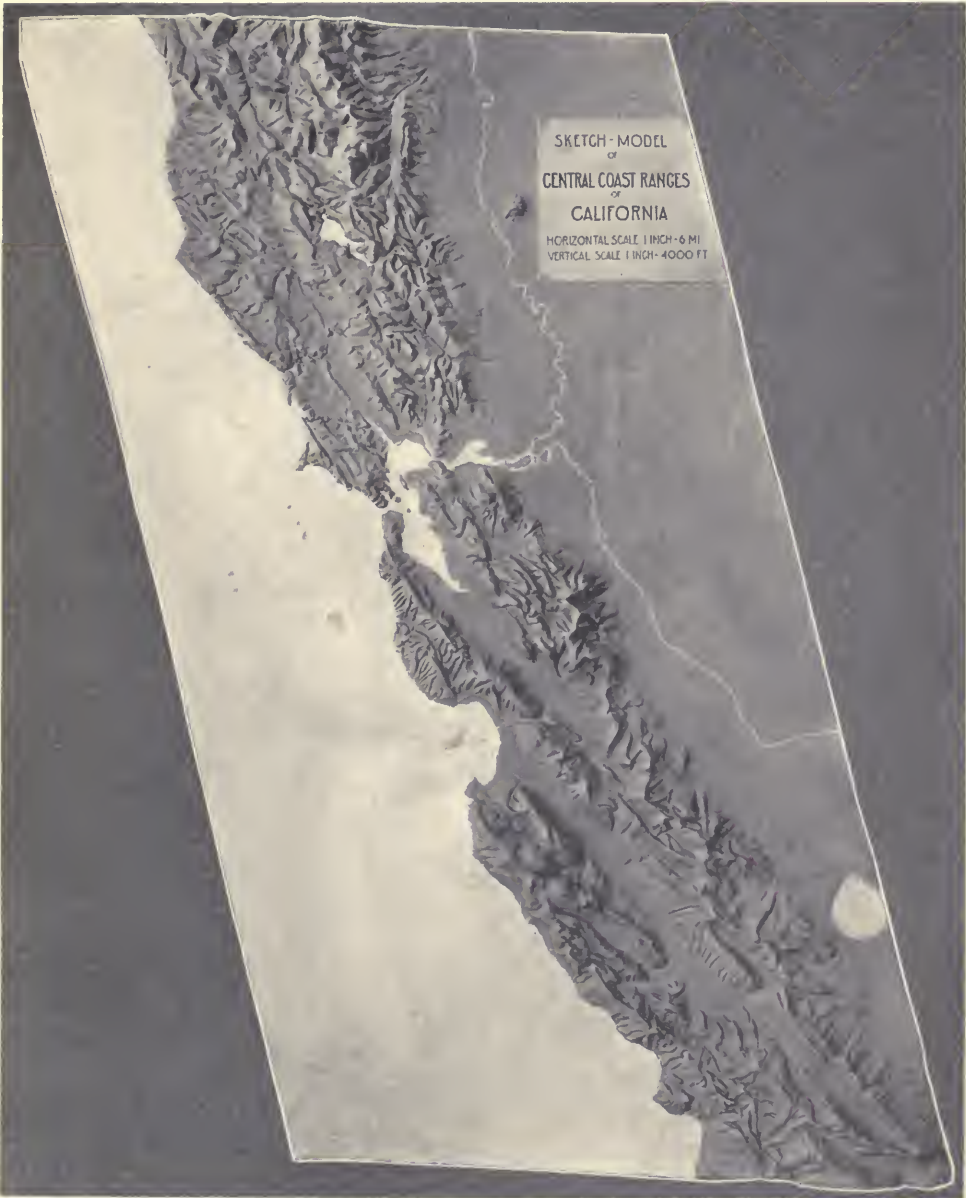




PLATE 13

CENTRAL COAST RANGES OF CALIFORNIA

The sketch model represented on this plate is thought to be correct to the extent of giving a reasonably accurate impression of the general features of the central coast region of California. No reliable topographic maps exist for the major portion of the area shown. The exact elevation of the mountains of the extreme northern portion is known in relatively few instances; elevations south of the Golden Gate are fairly accurate.



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PLATE 14

ELK VALLEY

Figure 1. Looking northwestward up the western portion of Elk Valley toward the divide which runs transversely across the valley floor in the extreme distance.

Figure 2. The bay portion of the pass, looking southwesterly toward the same divide. Both views fail to include the full height of the hills bordering the pass.



Fig. 1



Fig. 2

PLATE 15

LAGOON PASS

Figure 1. The flat valley floor in the view is the indefinite divide from which the water flows westward to the ocean and eastward to the bay. A low-grade alluvial cone built out from the left toward the hills on the right (the north) leaves a slight depression which during heavy rains drains both westward and eastward.

Figure 2. Ten miles westward from the divide in figure 1 above, Walker Creek, the western branch of Lagoon Pass becomes the narrow, youthful gorge shown in the lower view of the plate. The very flat top of the hill in the upper left-hand corner of the picture is characteristic of all the hilltops of the vicinity.

UNIV. OF
CALIFORNIA



Fig. 1



Fig. 2

70. 11/11/11
A. 11/11/11

PLATE 16

WALKER CREEK BRANCH OF LAGOON PASS

Figure 1. Old erosion surface, elevation six to eight hundred feet, in which the gorge at the mouth of Walker Creek is cut.

Figure 2. The gorge of Walker Creek which crosses from right to left the middle distance of the view above. The flat, graded floor of the gorge is due to sedimentation following recent subsidence.



Fig. 1



Fig. 2

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PLATE 17

SAN ANTONIO BRANCH OF LAGOON PASS

Figure 1. A view taken looking downstream in the valley of San Antonio Creek. The topography is that usually characterizing views taken looking toward the headwaters of a stream.

Figure 2. A view southward across the San Antonio.

The present valley floor slopes to the eastward (the left in the photograph), while above are portions of the former valley floor sloping westward.



Fig. 1



Fig. 2

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PLATE 18

LIBERTY GAP

Figure 1. The divide separating bay from ocean is marked approximately by the row of trees on the skyline. The elevation of one hundred and fifty feet for the lowest part of the crestline in Liberty Gap was taken in the larger opening in the trees. The knoll in the central foreground is a monadnock of harder rock.

Figure 2. Estero San Antonio, the creek heading against the low divide shown above, when it nears the ocean cuts a gorge through the hills shown in the distance in this view. These hills are really quite flat-topped and front the ocean with an escarpment three hundred to four hundred feet high.



Fig. 1



Fig. 2

PLATE 19

Figure 1. Old topography characteristic of the middle and upper course of the Estero San Antonio which flows westward from Liberty Gap.

Figure 2. Meadow in the alluvial floor of a little tributary to Walker Creek. This tributary was the harbor for Tomales until 1875.



Fig. 1



Fig. 2

PLATE 20

Figure 1. View of model of San Francisco Peninsula showing Merced Valley, a structural depression leading from the bay to the ocean. Model by Professor A. C. Lawson, Department of Geology of the University of California.

Figure 2. Alluvial fan at foot of Hood Mountain on east side of Sonoma Valley. The stream which formed the fan has evidently in the past flowed sometimes northward into the drainage basin of Russian River and sometimes southward into San Francisco Bay. This alternation of flow must have offered opportunity for the mingling of the species of fish which run to the headwaters.

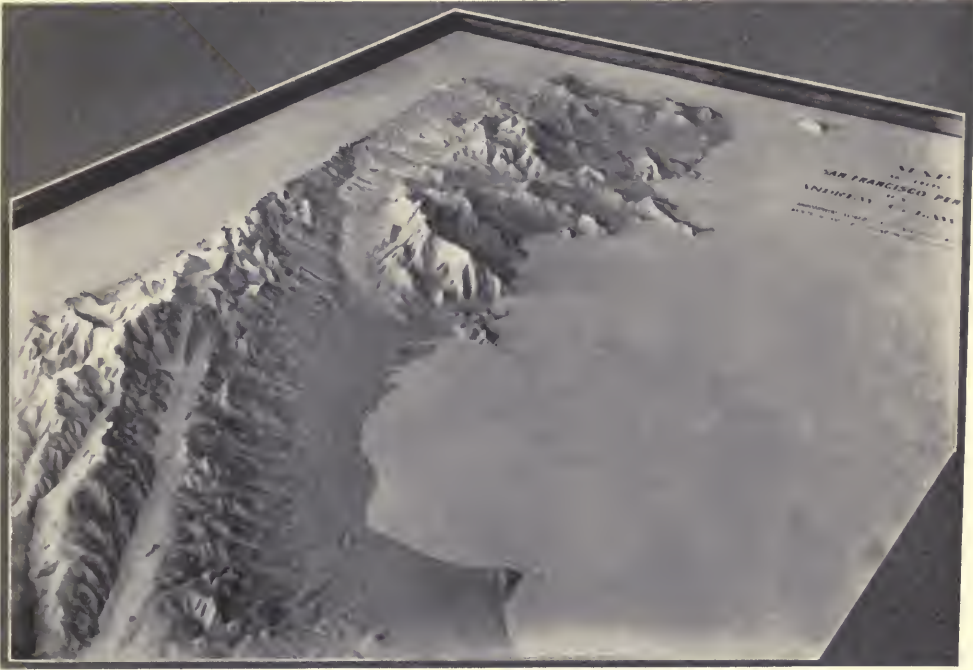


Fig. 1



Fig. 2

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